# Radiant Barrier Performance during the Heating Season

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## ABSTRACT

Results of winter experiments conducted in Central Texas are presented. The experiments were side-by-side tests using two identical 144 $ft^2$ houses which responded similarly to weather variations prior to any retrofit. Two radiant barrier orientations were tested, horizontal barrier and barrier against the rafters, in vented and non-vented attics. The results compiled in this paper are for attics with R-19 fiberglass insulation.

The data showed that radiant barriers were still effective during the winter season. During a typical day radiant barriers prevented approximately 9-17 percent of the indoor heat from escaping into the attic.

No significant difference in moisture accumulation was detected in the attic with the radiant barrier.

## INTRODUCTION

Radiant barriers have received increased attention during the past decade by energy producers as well as consumers. To the producers, radiant barriers have the potential to decrease peak demands, thus lowering their operational costs. To the consumers, radiant barriers offer some monetary savings produced by lower heating and cooling energy bills.

Radiant barriers are thin aluminum sheets characterized by having at least one low emissivity surface ($e < 0.05$). This low emissivity surface in conjunction with the attic air space reduces the amount of infrared radiation that can be transferred to and from the conditioned space.

Unfortunately, radiant barrier effectiveness is not the same all year round. Therefore, there is the need to evaluate such effectiveness during different times of the year. Radiant barriers have proven to be effective during the summertime in reducing the overall heat gain [1-10,13]. In some instances, radiant barriers have been reported to be effective in reducing heat loss from the conditioned space during the winter time [11,12]. However, in hot and humid climates, winters are short and not extremely cold. There also exists the possibility of moisture accumulation beneath the radiant barrier which can eventually damage the house ceiling. These concerns needed to be investigated.

This paper presents the results of winter experiments carried out during the winters of 1989-90 and 1990-91 in Central Texas. The instrumentation is discussed first followed by the experimental set up. Results of null tests as well as results of all experiments are presented later followed by a brief summary and conclusion.

## INSTRUMENTATION

Each test house was instrumented with approximately 120 sensors. The sensors included: Type T thermocouples (T/C), surface heat flux meters (HFM), relative humidity transmitters (RH), and watt-hour counters and watt-hour meters.

All the data were recorded by means of a data logger. The data were collected at 1-minute intervals and integrated every hour. The integrated values were then sent to a micro-computer for storage and analysis.

Temperatures were recorded for the indoor room, attic air, roof, attic deck, and ceiling, as well as across the fiberglass, and for the ambient air and the ground. Each of the temperatures in question was measured using grids of T/C's connected in parallel. The indoor room temperature was measured by a grid 4.5 ft. from the floor. Attic air temperatures were measured at different levels 5 in. apart from the bottom to the underside of the roof. Attic air temperatures also were measured at different distances from the centerline and at different levels. Temperature distribution across the fiberglass insulation was recorded at 0 in., 2 in., and 4 in. from the top of the insulation.

Each test house was instrumented with five (5) HFMs (4.0"x4.0"x3/32") with calibration traceable to NIST standards. Four HFMs were inside each house and one was in the floor of the attic. One of the four HFM measured the heat flux through a ceiling joist. All reported heat flux readings were weighted averages of all HFMs.



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Heat was provided by electric resistance heaters. These heaters were connected to watt-hour counters and watt-meters. The watt-hour counters kept track of heating input to each house during entire testing periods while the watt-meters sent instantaneous values to the computer in 10-second intervals which later provided daily integrated energy consumption for each house.

Total global sun and sky radiation on a horizontal surface was measured with a pyranometer whose calibration was traceable to NIST standards. An emissometer was used to measure the emissivity of any surface of interest.

## EXPERIMENTAL SET UP

The radiant barrier experiment was located in College Station in Central Texas. The area climate is humid subtropical with mild winters. During the winter seasons, temperatures are mild with daily averages estimated at 62 °F. The mean relative humidity for the area is high, ranging from 51-62 percent at noon CST. The estimated possible sunshine during winters is 48 percent.

The radiant barrier experiment was composed of two test houses labeled "west" and "east". The ridge line ran west-east in both houses. The nominal floor areas were 12 ft. x 12 ft. with 8 ft. floor to ceiling distance. The houses were built 25 ft. apart from each other. No shadow was cast on them from any direction. Trees were located on the north side of the houses.

The houses were 144 $ft^2$ with 8 in. walls and had slab-on-grade foundation. The walls were constructed of a 2 in.-by-6 in. frame with R-19 paper-faced fiberglass batt insulation. The exteriors and interiors were completed with 1/2 in. sheathing and 1/2 in. gypsum board, respectively. The ceiling also was made up of a 2 in.-by-6 in. framing, with R-19 unfaced fiberglass insulation and 1/2 in. gypsum board. The houses' three window areas, (one on each side except south), were filled with insulation board inserts. This eliminated a significant heat gain/loss through the envelope and forced a major part of the load to proceed from/to the attic. A vapor barrier was placed in the interior part of the walls to minimize any air infiltration which might occur. The roof was made of asphalt shingles over 1/2 in. plywood sheathing. There was a 12-inch overhang on the north and south sides.

The attics originally were built with gable vents which provided natural ventilation. To be able to measure the airflow rates, the gable vents were sealed with removable inserts. New inlet and outlet ventilation areas were made. The inlet area was a strip 1.5 in. by 10 ft. located on the east side of each house and 3 inches above the ceiling frame. The outlet area was a 4 in. diameter hole fitted with an attached fan. The outlets were located 25 in. above the ceiling frame. The fan induced airflow currents. Located at the exhaust side of each fan was a damper mechanism to control the airflow rates. To set the airflow rates, the static pressure curves of each fan were obtained experimentally at the test site. A static-pressure gauge was attached to each fan and provided the information on the amount of air volume per unit time that was being removed from each attic. The fans had a 1/20 HP motor and operated on a continuous cycle.

Both houses were equipped with identical Fan Coil Units (FCU), digital thermostats and electric resistance heaters. Both heaters were identical and rated at 4100 Btu/hr. These heaters were directly connected to the thermostats and to watt-hour counters and watt-meters. The watt-hour counters kept track of the heating energy consumption for different testing periods. The watt-hour meter sent the instantaneous data to the data logger in intervals of 10 seconds. The 10-second data was later integrated on a daily basis to obtain daily heating energy consumption.

## CALIBRATION PERIOD

Calibration periods were run prior to any retrofits. The calibration period for the winter tests of 1989-90 started on January 13, 1990 and ended on January 30, 1990. During this time, overall heating energy consumption, ceiling heat fluxes, and indoor temperatures as well as attic temperatures were monitored. During the first part of this period, from January 13-18, overall energy consumption in both houses, indoor temperatures and attic temperatures were compared. The results are presented in Table 1.

From the data presented in Table 1, it was deduced that both houses responded similarly to weather variations. Therefore, any variations in their responses after the retrofit was made were assumed to be produced by the radiant barriers. For this calibration period, the heating energy consumption difference was 1.1 percent. Attic and indoor temperatures were also similar. During January 24-30, 1990 ceiling heat fluxes were compared. Their dynamic responses are presented in Figure 1. The ceiling heat fluxes were less than 1 percent different. During the calibration periods, both attics were naturally vented and had R-19 fiberglass insulation level with radiant barriers.

Table 1. Winter 1989-90 House Calibration Period.

| CALIBRATION PERIOD | | | |
|---|---|---|---|
| Period | January 13-18, 1990 | | |
| House | West | East | % Diff |
| Energy Use (Btu) | 62931 | 62225 | 1.1 |
| Avg Indoor Temp (°F) | 69.6 | 69.6 | 0.0 |
| Avg Attic Temp (°F) | 63.4 | 63.4 | 0.0 |
| Avg Deck Temp (°F) | 63.9 | 63.9 | 0.0 |
| Avg Shingle Temp (°F) | 63.1 | 62.9 | 0.3 |
| Avg Outdoor Temp (°F) | 62.5 | | |

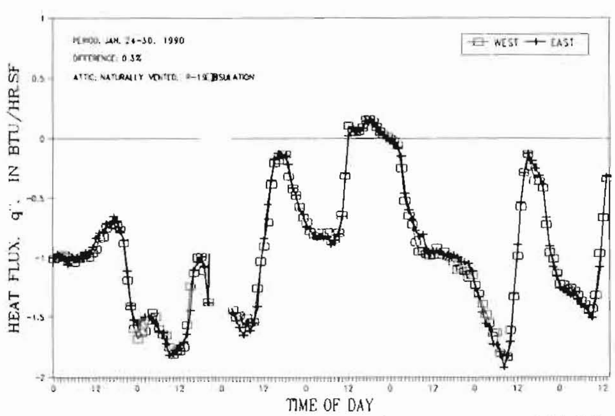


Figure 1. Ceiling heat fluxes for winter 1989-90 calibration. Tracking started on Jan. 24 at 00:00 and ended on Jan. 30 at noon.

For the winter season of 1990-91 no additional null tests were run. Winters in Central Texas are fairly short and mild. Extra null tests limit the number of radiant barrier tests that can be performed during short winter periods. However, null tests were run during the months of June 1990 and April 1991 which confirmed that the houses still responded similarly to weather variations.

## RESULTS

Winter tests were carried out on the winters of 1989-90 and 1990-91. Prior to any retrofits both test houses behaved similarly to weather variations. Therefore, any changes recorded in overall energy consumption and ceiling heat fluxes were attributed solely to the radiant barriers. Some corrections were introduced to account for minor differences in room temperatures which occurred during testing.

The experiments were well controlled. Normally the room temperatures were controlled within 0.4 °F. Attic airflows were metered and carefully controlled. The data recorded included surface and air temperatures of attic components and attic spaces, ceiling heat fluxes, indoor temperatures and relative humidities. Relative humidity sensors were placed under the fiberglass in both attics. There seemed to be a concern that on cold winter mornings radiant barriers would create condensation under the barrier which would eventually damage the ceiling structure of the residence. Results of these measurements are presented later.

The radiant barriers produced reductions in the daily integrated ceiling heat flux from the heated space to the attic. These reductions were approximately 9-17 percent depending on the weather. Rainy and cloudy days produced higher reductions than did cold but clear winter days because on clear days the shingles were heated up by solar radiation, in some cases producing a ceiling heat flux into the conditioned space which the barriers blocked a fraction of. This heat blockage was not desired during this time because extra heat entering the house from the ceiling resulted in reduced heating energy requirements from the heating systems.

Results of four experiments are presented in Table 2. These included two radiant barrier configurations with two attic airflows per configuration. Radiant barrier performance was tested for a horizontal radiant barrier placed over the fiberglass insulation with an attic under full and no ventilation conditions. These results were compared to a house without radiant barrier but under the same two attic airflow conditions. The same results are presented for attics with a radiant barrier attached to the rafters. This configuration is known as the 'truss' configuration.

Table 2. Ceiling Heat Flux Percent Reductions Produced by Radiant Barriers.

| Configuration | Attic Fully Vented (> 1.0 Cfm/ft$^2$) (%) | Attic Non-Vented (%) |
|---|---|---|
| Horizontal | 14 | 16.5 |
| Truss | 9 | 14.5 |

The results indicated that horizontal radiant barriers produced larger savings than the truss radiant barrier. It was also shown that radiant barriers were more effective in reducing ceiling heat flux from the conditioned space when attics were non-vented. This was expected since under non-vented attic conditions the radiation component in the overall heat transfer process was relatively larger than in the case when the attics were fully vented. Having a non-vented attic also reduced the magnitude of the ceiling heat flux to the attic.

It is important to note that the results presented in Table 2 were from short test periods (only 7-10 days) because winters are mild in this area and do not last long. It was in the interest of the researches to test the radiant barriers during 'severe' cold weather periods. Usually, severe cold weather in Central Texas is accompanied by rainy or cloudy days. It is believed that the results presented in Table 2 would be somewhat lower if longer periods of time would have been used which would have accounted for more clear as well as overcast days.

Figure 2 depicts ceiling heat fluxes in side-by-side comparison of houses with and without radiant barriers. These trends were typical during winter days.

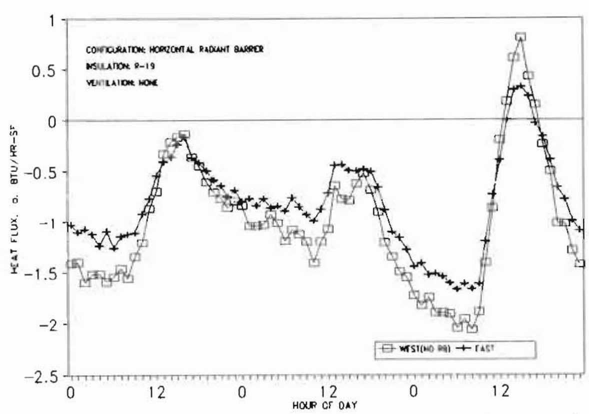


Figure 2. Ceiling heat fluxes for horizontal radiant barrier in non-vented attics (January 14-16,1991).

Figure 2 clearly depicts the performance of a radiant barrier. Negative heat flux meant from the conditioned space to the attic. The house with a radiant barrier had less heat loss through the ceiling, but it also admitted less heat to the house during warmer periods of the days, thus lowering the integrated efficiency of the radiant barriers.

Figure 3 depicts the indoor and ambient temperatures for the same period as Figure 2. This is to show how well controlled the experiments were. The ambient temperature profile is typical of the region during winter seasons.

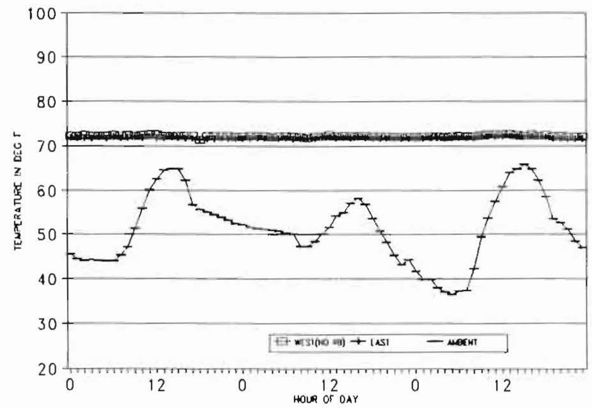


Figure 3. Indoor and outdoor temperatures. (Same period as Figure 2) .

There was some concern about the negative effects that a horizontal radiant barrier could have on the ceiling of a house if it provided a mechanism for moisture to accumulate. Relative humidity data collected during the winter experiments suggested that the installation of a horizontal radiant barrier did not significantly increase the amount of humidity in the fiberglass. It is important to point out that the radiant barrier used was perforated. Figure 4 shows the relative humidity in the fiberglass. The data is also for January 14-16, 1991.

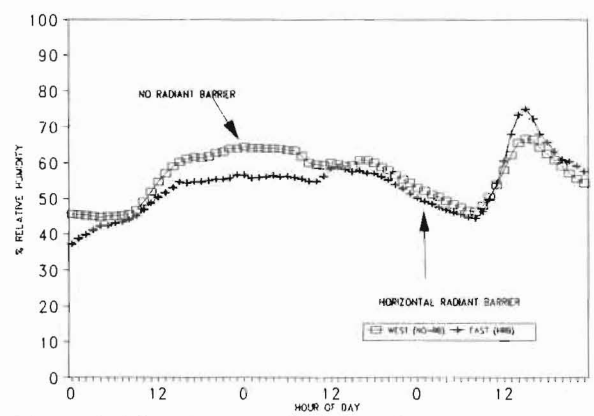


Figure 4. Fiberglass Relative Humidity. (same period as Figure 2).

For mild winters such as the ones experienced in this region, the magnitude of heat flux through a ceiling with R-19 was low (peaks of ~ 2 Btu/hr-ft$^2$); therefore, even though percent differences in ceiling heat flux were recorded, the instrumentation measuring overall energy consumption did not detect any direct savings in overall heating energy. The test houses used had a higher envelope area to ceiling area ratio than is typical of houses and only 8-13 percent of the overall heating load entered through the ceiling.

## SUMMARY AND CONCLUSIONS

Radiant barrier experiments were conducted under winter conditions in a hot and humid climate. The experiments were of a side-by-side type. Both houses responded similarly to weather variations prior to any retrofit. Then, all changes recorded after the retrofit were attributed to the radiant barriers. The experiments were carried out during the winters of 1989-90 and 1990-91. Two configurations were tested, and two airflows per configuration were used. The airflows were full ventilation (usually > 1 CFM/sf) and no ventilation.

The radiant barriers produced a reduction of ceiling heat flux from the conditioned space to the attic of approximately 9-17 percent. The horizontal radiant barrier proved to be more effective than the truss radiant barrier. A non-vented attic not only reduced the magnitude of the ceiling heat fluxes but produced a higher percent reduction in combination with a radiant barrier.

Relative humidity measurements of the fiberglass indicated that the use of a perforated radiant barrier did not significantly increase the humidity in the fiberglass insulation which suggests that moisture accumulation will not be increased by the use of a horizontal radiant barrier.

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